# Hawai‘i Natural Energy Institute Research Highlights

*Advanced Materials*

## *Encapsulation of Perovskite Solar Cells for Long Term Operations*

**OBJECTIVE AND SIGNIFICANCE**: The primary objective of this program is to invent innovative encapsulation techniques that can enhance the operational lifespan of emerging low-cost, high-efficiency perovskite solar cells (PSCs). These advancements have the potential to help the U.S. Department of Energy (DOE) meet its commitment to reducing the cost of photovoltaics to \$0.02/kWh, making solar energy more accessible and affordable.

**BACKGROUND**: Since the first report of PSCs in 2009, tremendous research efforts on absorber chemistry have boosted the power conversion efficiency of this material class from 3.9% to 25.7%. Although impressive, this attribute alone cannot guarantee the commercial success of PSCs, as any emerging technology must also meet the 20-25 year stability already achieved by other mature photovoltaic (PV) classes. To date, the durability of best performing PSCs is limited to a few months at best, constituting an important roadblock in their deployment.

**PROJECT STATUS/RESULTS**: In this project, HNEI partners with the National Renewable Energy Laboratory (NREL) to accelerate the development of unique protection schemes to enhance PSCs lifetime. Specifically, our team aims at eliminating two stress factors responsible for PSC degradation: high temperatures during processing (technical barrier #1) and atmospheric effects during PV operations (technical barrier #2).

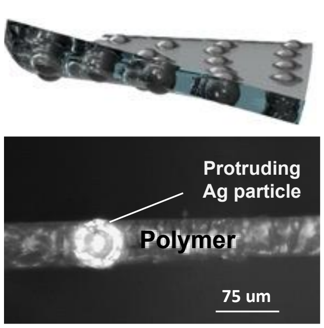
HNEI has developed a new composite integrating multi-functionalities, such as *corrosion resistance*, *lightweight* and *flexibility*, as well as *tunable optoelectronics*. Unlike most conductive flexible polymers, where media are coated on top providing only *in-plane* conductivity, HNEI’s transparent conductive composites (TCC) innovate by allowing simultaneous high optical transparency (%T>90% in the 370 nm-2000 nm region) and high *out-of-plane* electrical conductivity (R<0.2 $\Omega.cm^2$). This unique characteristic is permitted by highly conductive 50-micron Ag-coated PMMA spheres protruding out of a transparent non-conductive polymer.

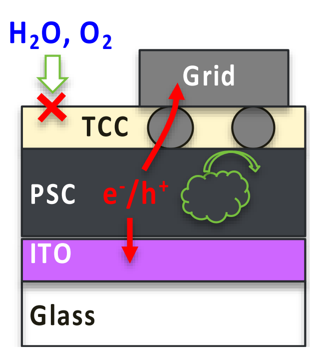
In this project, TCCs serve as gas-barrier located between the PSC and metal top contacts, providing a conformal hermetic seal repelling moisture and oxygen while preventing out-diffusion of volatile species. TCCs offer at least three main advantages over traditional “glass-glass” encapsulation.

First, our composite fully cures at room temperature (addressing barrier #1) – eliminating all adverse thermal effects encountered in conventional sealant/adhesive technologies, which require curing above 100°C. Also, the protruding particles in TCC act as direct electrical access points to the underlaying structure. Therefore, the coating is not spatially restricted and can be applied directly on top of the PSC and can extend to the device edges, sealing directly the top and sides of the PV stack to the operating environment (addressing barrier #2) with no risk of lateral electrical shorting. Finally, there is no need for an extra encapsulating glass cover with TCCs, reducing module weight and cost.

Our team has demonstrated that TCCs can maintain virtually 100% of their optical and electrical properties for over 1,000 hours of outdoor exposure under Hawai‘i’s tropical semi-arid climate, while TCC-coated PSCs preserve over 90% of their initial efficiency after 1,300 hours of accelerated testing under 45% relative humidity at 50°C.

Current efforts are focused on reducing TCC’s water vapor and oxygen transmission rates to meet packaging standards.




Hawai‘i Natural Energy Institute | School of Ocean & Earth Science & Technology
University of Hawai‘i at Mānoa, 1680 East-West Road, POST 109 • Honolulu, HI 96822
Phone: (808) 956-8890 • Fax: (808) 956-2336 • www.hnei.hawaii.edu

To date, this research has produced the following works:

- 2024, K. Outlaw-Spruell, J. Xu, Q. Jiang, K. Zhu, and N. Gaillard, **Transparent Conductive Composites – Novel Encapsulation Scheme for organic photovoltaics show potential as a dual functioning transparent electrode and barrier system**, Poster presented at the U.S. DOE Solar Energy Technology Office Peer Review, March 26-27, Washington, DC Photovoltaics Research Track.
- 2023, K. Outlaw-Spruell, J. Xu, Q. Jiang, K. Zhu, and N. Gaillard, **Transparent Conductive Composites—A New Class of Encapsulants for Durable Perovskite Photovoltaics**, Presented at the Materials Research Society Spring Meeting, April 10-14, San Francisco, California, Symposium EL02.17.04.

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*Contact*: Nicolas Gaillard, ngaillar@hawaii.edu

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